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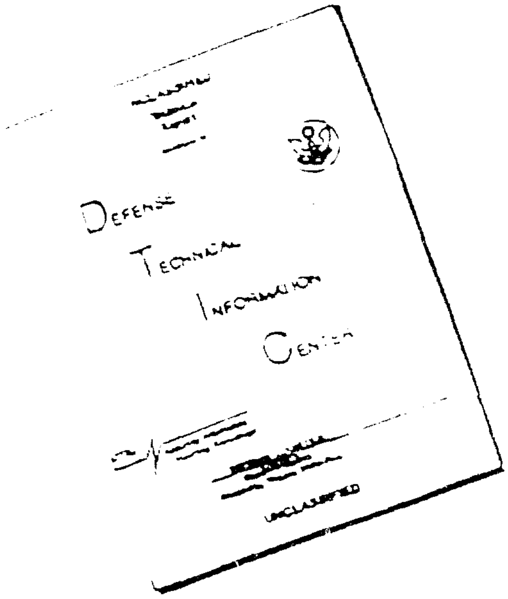

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PROJECT ARTEMIS
HIGH POWER ACOUSTIC SOURCE
SECOND INTERIM REPORT ON ACOUSTIC PERFORMANCE

[UNCLASSIFIED TITLE]

A. T. McClinton and R. H. Ferris

SOUND DIVISION

19 September 1961

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the reason reported therein, as appropriate.

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(7) NRL MEMORANDUM REPORT 1214

(6) PROJECT ARTEMIS,

HIGH POWER ACOUSTIC SOURCE,

SECOND INTERIM REPORT ON
ACOUSTIC PERFORMANCE (Second) (U).
(Unclassified Title)

(8)

(14) NRL-MR-1214

...Unauthorized Disclosure Subject to Criminal Sanctions

(12) 33p.

by
(10) A. T. McClinton
R. H. Ferris

19 September 1961

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Electrical Applications Branch
Sound Division
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ABSTRACT

U. S. Naval Research Laboratory Memorandum Report number 1205 presented the results of initial acoustic tests with the interim ARTEMIS source array. This report describes additional tests which were conducted on the same array but with the acoustic pressure release system removed. Displacement amplitude and phase of 23 of the 144 transducer elements were measured for frequencies in the band from 250 to 600 cycles per second. The tests revealed that displacement amplitude and phase varied widely with element position and operating frequency. The elements on the array edges tended to have higher displacement amplitudes and phase discontinuities than inner elements.

PROBLEM AUTHORIZATION

ONR NR 287 002 (Special)
NRL Problem Number 55S02-11

PROBLEM STATUS

This is an interim report on one phase of the project. Work is continuing.

 [redacted]

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INTRODUCTION

An array of 144 electromagnetic transducer elements was installed on the USNS MISSION CAPISTRANO (T-AG 162) for the purpose of determining its acoustic performance. U. S. Naval Research Laboratory Memorandum Report 1205 presented the results of the initial acoustic tests. In the period following these tests the transducer was operated at limited power in propagation experiments. At that time certain malfunctions occurred in the pressure release system which indicated that further study of the motional characteristics of the array was required.

During the initial tests accelerometers had been attached to two elements of the transducer array. Although it was recognised that a wider sampling was desirable, time did not permit relocation of the accelerometers. With the pressure release system in place it is necessary to reverse a transducer element in its mounting in order to attach an accelerometer. This is a laborious and time-consuming procedure. In order to facilitate a wider sampling of element displacements, the pressure release tubes were removed from the transducer for the tests described in this report. Thus, accelerometers could be attached without reversal of the elements. With the tubes removed, radiation was no longer confined to the forward direction.

The transducer elements composing the array are type TR-11C manufactured to NRL specification by Massa Division, Cohu Electronics, Incorporated. They are variable reluctance type units. Each element is 11-1/8 inches square on the radiating face and 11-3/4 inches deep. They are assembled in modules six elements wide by twelve elements high. Two such modules were installed on the array structure forming an array composed of 144 close-packed transducer elements, approximately one wavelength square at the resonant frequency. The installation is shown in Figure 1.

The six elements in each module row were connected in series electrically and the twelve rows were connected in parallel. The two modules were then connected in parallel in an oil-filled junction box. Thus the array consisted of 24 parallel groups of six series elements. The dc polarizing power as well as the ac power was supplied to this grouping.

PURPOSE

The purpose of this experiment was to obtain information regarding element displacement amplitude and phase as a function of frequency

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and element position in the array. While time did not permit the sampling of each of the 144 elements, an attempt was made to obtain a reasonable sample which would be indicative of the behavior of the entire array. Acoustic response on the reciprocal acoustic axis as well as the array impedance were also measured for the purpose of monitoring the transducer performance.

EXPERIMENTAL PROCEDURE

Experiments were conducted during the period of 27 to 28 June 1961 in the Chesapeake Bay near Cape Charles, Virginia, in a water depth of 90 feet. When operating, the array was submerged to a depth of 36 feet at its center.

Polarizing power at ten amperes per element was supplied by a diesel-driven generator. Signal current was supplied from a 1300 kilowatt Ling amplifier.

Instrumentation was provided to measure the input parameters of dc polarizing current, ac current, voltage, power and frequency. Two accelerometers were employed to measure the displacement amplitude and phase at the radiating faces of the transducer elements and a monitor hydrophone located 17 feet on the back center-line of the array measured the acoustic field at that point. Although this hydrophone was at the furthest point on the array structure back of the two modules, it must be recognized that reflection interference from structural members might well affect the accuracy of measurements at this point. The proximity of bottom, surface and ship's hull boundaries undoubtedly affect the acoustic field.

Displacement data were obtained by means of a pair of R104 accelerometers which were screwed into tappedholes on the rear faces of the transducer elements. The displacement amplitude and phase of two elements were measured as a function of frequency in each data run. At the conclusion of each run the array structure was raised and the accelerometers repositioned. The accelerometers have been calibrated both in air and in water. The latter has involved both an acoustic and nonacoustic ambient. The output of these units was not affected by the ambient conditions.

EXPERIMENTAL RESULTS

Twelve data runs were completed. In each run the ac voltage, current, and power as well as the accelerometer and hydrophone outputs were

 [redacted]

measured and recorded as the frequency was varied in 22 increments from 250 to 600 cycles per second. The phase of each accelerometer output relative to the driving oscillator voltage was estimated to the nearest ten degrees by observing an oscilloscope presentation with triggered sweep.

An ac current of 10.4 amperes and a dc polarizing current of 240 amperes were used throughout all runs. During the first run, data were also obtained with ac currents of 5.2 and 15.6 amperes. However, all of the statistical information presented in this report is taken from data obtained with 10.4 amperes alternating current. The two accelerometers were repositioned after each run so that displacement data were obtained for 23 transducer elements with one element being sampled twice. Figure 2 illustrates the element positions that were sampled. Note that the rows of elements are numbered one through twelve from top to bottom, and the columns from one through six from left to right for each module. Module serial number six is on the left and five on the right as one faces the array. An individual element position is designated by three numbers. The first indicates the module, the second the row, and the third the column. For example, element position number 6-5-3 is in module number six, row five, column three.

Figures 3, 4 and 5 are plots of the resistive, reactive and total transducer impedance respectively. Values are for the entire 144 element array and are the arithmatic means of the data for each of the twelve runs. The data are plotted at nominal values of frequencies although measured values varied as much as ±0.5 cycles per second. The vertical lines indicate the separation between maximum and minimum values of amplitude and thus the spread in data. Figure 6 is a vector impedance locus diagram for these same values. It is evident from the data on Figures 3, 4 and 5 that there are many secondary resonances. In addition to those shown, which may be of even higher amplitude than indicated, there probably are others at those frequencies where there is a large spread in data for the twelve runs.

Figures 7a through 9b illustrate transducer displacement along columns three and six and row seven in module number six. The location of these elements is as illustrated in Figure 2. It is to be noted that, in general, the outer edge elements tend to have large displacements relative to those in the remainder of the module, and adjacent elements often have remarkably different displacements. Figure 10, in which the displacements are averaged for all frequencies in each column and row, illustrates the tendency for high displacements of outer elements. In the third column the inner elements have somewhat higher displacements than those of the sixth column or seventh row. However, all of these elements are in only the third position from an outer edge.

It should be kept in mind that while each element in a row is driven by the same current due to series connection, the current for any one row might be quite different than in other rows. For instance, all of the elements in an outer edge row experience a different loading than those in inner rows. At certain frequencies, the total impedance of an outer row could be far different from that of an inner row and thus be driven by a lesser or greater current. In general, it would be reasonable to expect the poorly loaded outer rows to have relatively high impedances.

The phase distribution, as illustrated in Figures 11a through 13b, is extremely random and shows little consistent pattern except that the outer elements, in most cases, exhibit a large phase shift relative to the adjacent element. It should be noted that, in several instances, adjacent elements display a full 180 degrees phase difference.

To demonstrate the degree of repeatability of the phase and amplitude data, the same accelerometer was attached to element position number 6-7-6 on two different runs. The results of the two runs are plotted in Figure 14. The agreement appears to be excellent with the exception of the phase data for the three highest frequencies.

There appears to be no similarity between the data taken at geometrically similar element positions. Element positions 6-6-3 and 6-7-3, 6-6-6 and 6-7-6, as well as 6-5-3 and 6-8-3 are in symmetric positions but it can be seen from Figures 7, 8, 11 and 12 that there is no corresponding correlation in phase or amplitude. Positions 6-1-1 and 5-1-6 are also symmetric and displacement amplitude for these two positions differed widely. However, the difference, in this case, is not conclusive since the element in position 5-1-6 showed evidence of having a broken spring.

The large displacement amplitudes evidenced by certain elements at some frequencies suggest that the acoustic loading is low. In order to obtain an average value of transducer loading, an rms displacement amplitude for all measured elements was computed at each operating frequency. These values are plotted as a function of frequency in Figure 15. From monitor hydrophone measurements the radiated power was computed at each frequency. These values are based on a best estimate of directivity index at each frequency since no directivity patterns were measured. If unity ρC loading and uniform velocity over the transducer face were assumed, the transducer displacement would be as indicated by the curve in Figure 15. The latter values of displacement appear to be approximately 20 decibels below the measured values. The effective average loading is, therefore, 0.1 ρC. As stated previously, the monitor hydrophone measurements are questionable due to the proximity of large structural members and surface boundaries to the hydrophone. The computed value of loading also depends on the assumed directivity index. Distortion of the acoustic directivity pattern, caused by the varying velocity distribution over the face of the array, could result in a change in the directivity index from the idealized value. Because of these factors, the computed acoustic loading could be in considerable error. Figure 15 illustrates that the resonant frequency of the array is lower than 400 cycles per second whereas it had been slightly above 400 cps when squash tube reflectors were used.

At the conclusion of the tests, each element was checked to determine whether failure had occurred during the prior period of operation. As a result of this test, it was found that 47 of the 144 elements were probably damaged. Figure 16 illustrates the pattern of the damaged elements. Each darkened square represents an element which shows evidence of being damaged. It can be seen that the pattern is random. It is not known when this damage occurred. While most of the tests described in this report were performed at ten amperes ac drive current, currents as high as 15 amperes were used in the first run. The propagation experiments which preceded these tests were conducted with 25 amperes current. Twenty-five amperes corresponds to a maximum total power input of approximately twenty kilowatts at resonance, or an average input power of 140 watts per element.

The elements displayed varying degrees of damage which might indicate one or more broken springs.

During the propagation experiments a number of the squashed tubes failed in fatigue and were replaced. In some positions, the tubes failed repeatedly. The positions in which tubes failed and the number of times they failed in that position are indicated in the following table.

	Number of Tube Failures	
Row	Module 6	Module 5
1	7	1
2	-	1
9	-	1
12	-	-

CONCLUSIONS

Tests of the interim 144 element ARTEMIS array indicate that the displacement amplitude and phase of individual elements vary widely with element position and operating frequency. Elements on the outer edge tend to have high values of displacement and large phase discontinuities relative to nearby as well as inner elements. The phase and amplitude distribution otherwise appears quite random and variations are disturbingly large. The average displacement is large, indicating poor acoustic loading, perhaps as low as 0.1 ρC when radiating from both faces of the array. A possible cause of the velocity variation is the small dimensions relative to a wavelength of the individual transducer elements. Minor variations in displacement caused by differences in individual elements or by normal pressure patterns, would be intensified by a resultant unloading of individual elements. The electrical series connection in element rows would further heighten the velocity variation by causing a relatively unloaded element to absorb more power by reason of its increased impedance. Other effects such as acoustic short circuiting via water circulation between adjacent elements might play a role. It is not known if the effects will persist in larger arrays. The principal causes of the velocity variations are not distinguishable at this time and the need for further experimentation is indicated. These experiments should be conducted with an array having the dimension of the final configuration since array size might be influential.

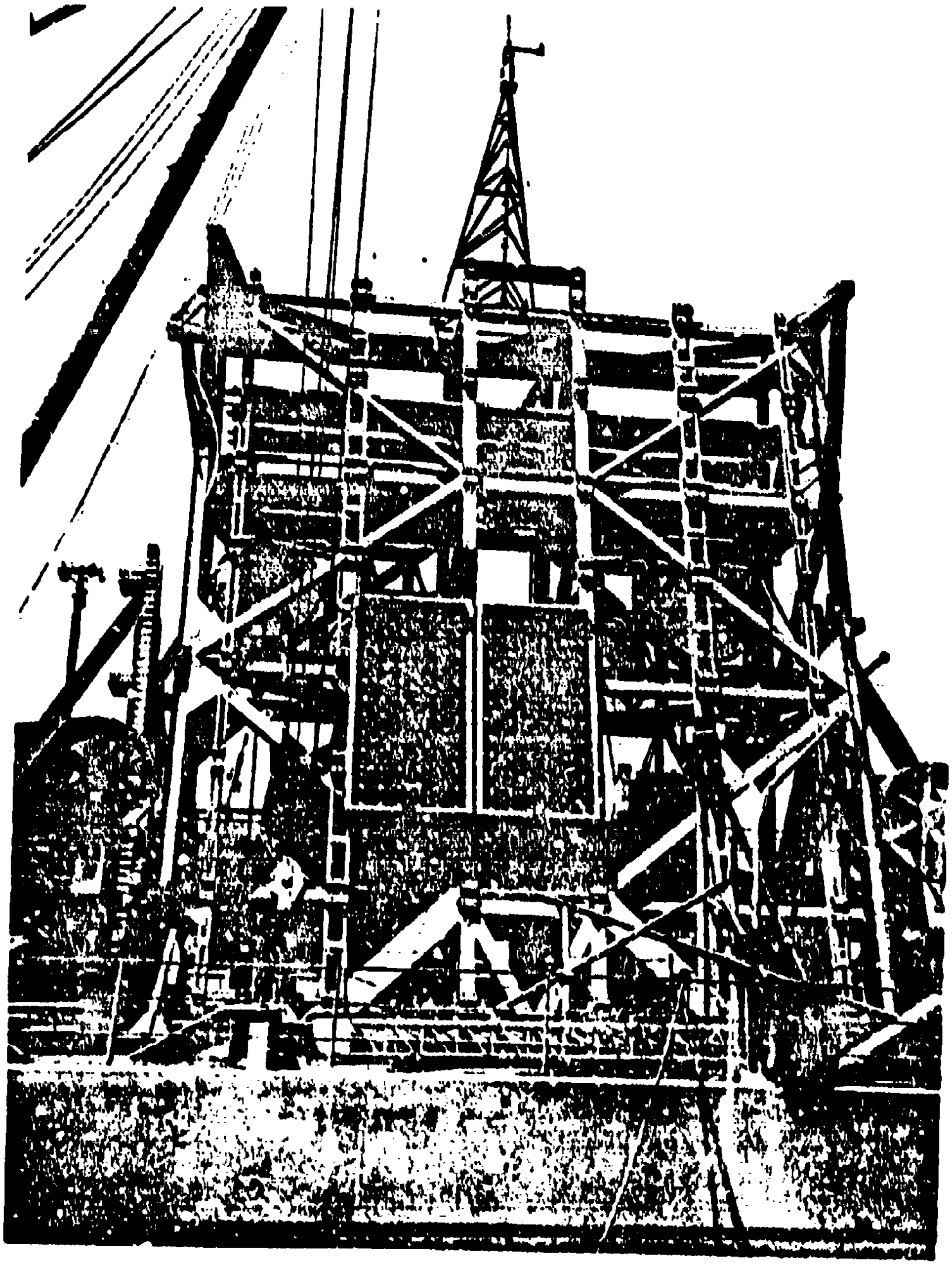

Fig. 1 - Photograph of array with two modules

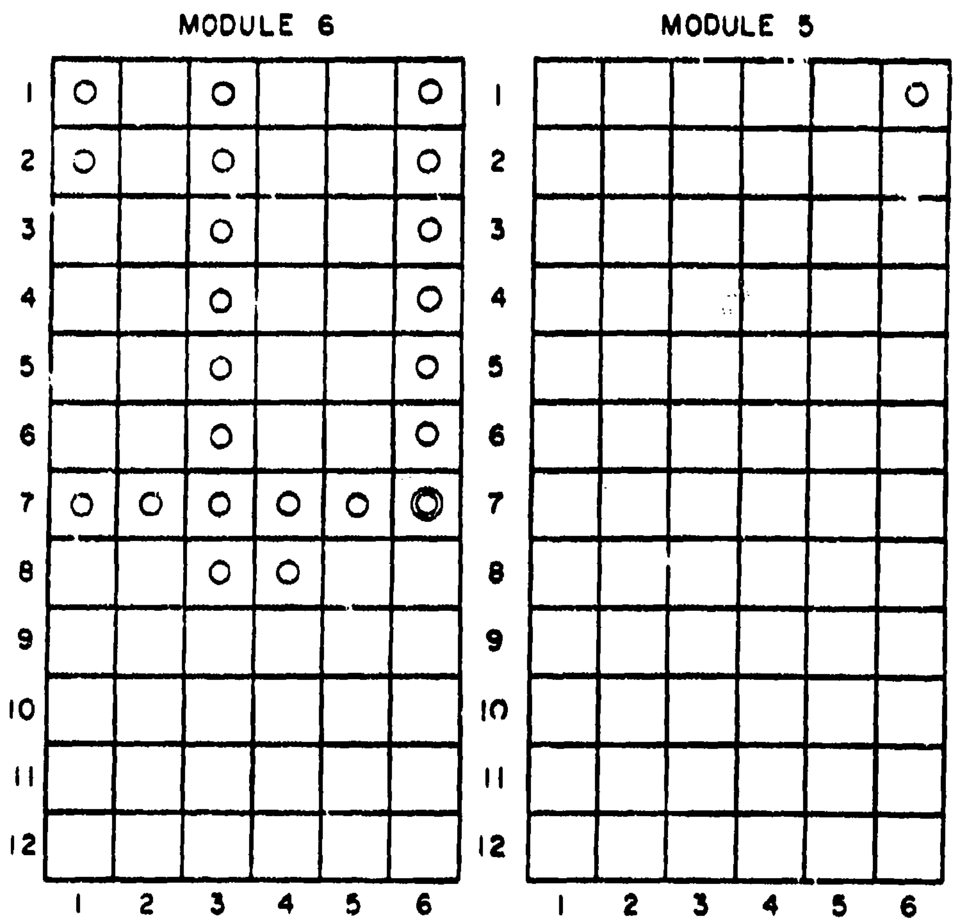

Fig. 2 - Element positions in the two module array. The circles indicate those elements to which accelerometers had been attached.

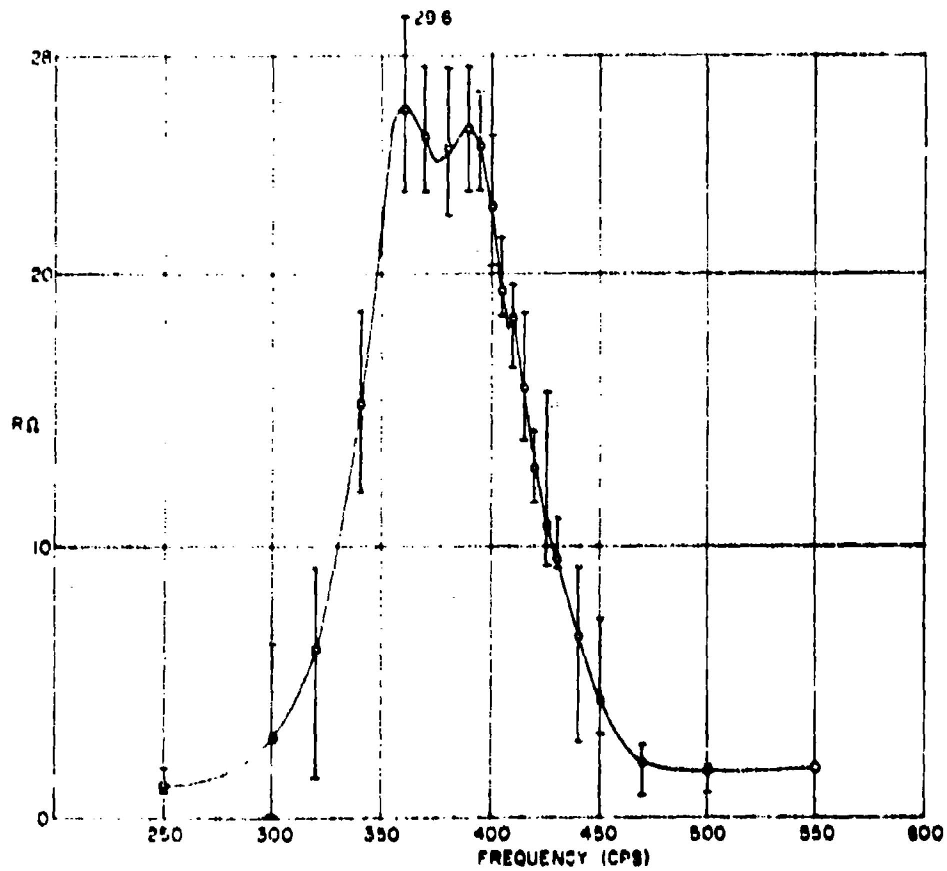

Fig. 3 - Averaged values of resistive component of transducer impedance

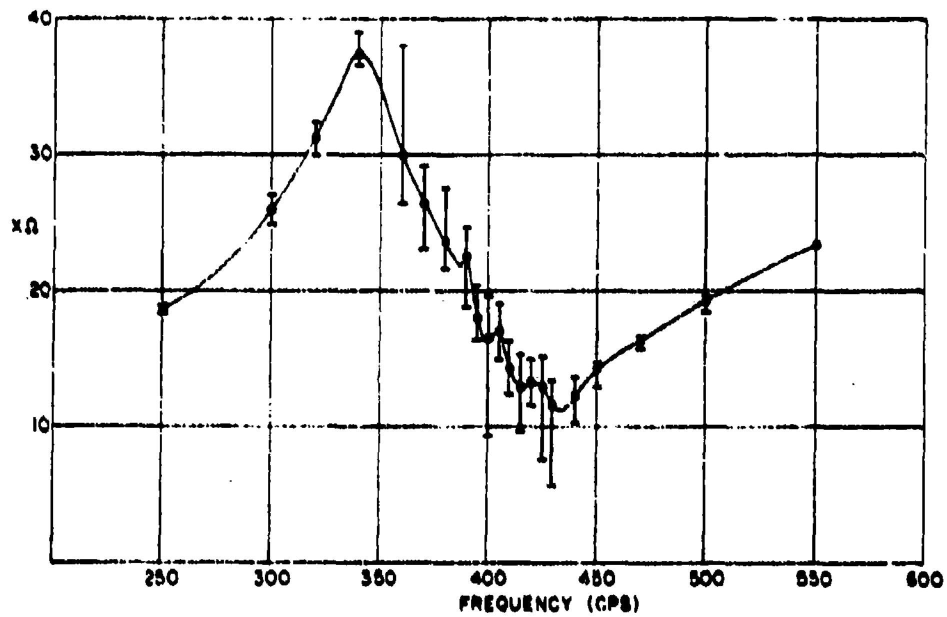

Fig. 4 - Averaged values of reactive component of transducer impedance

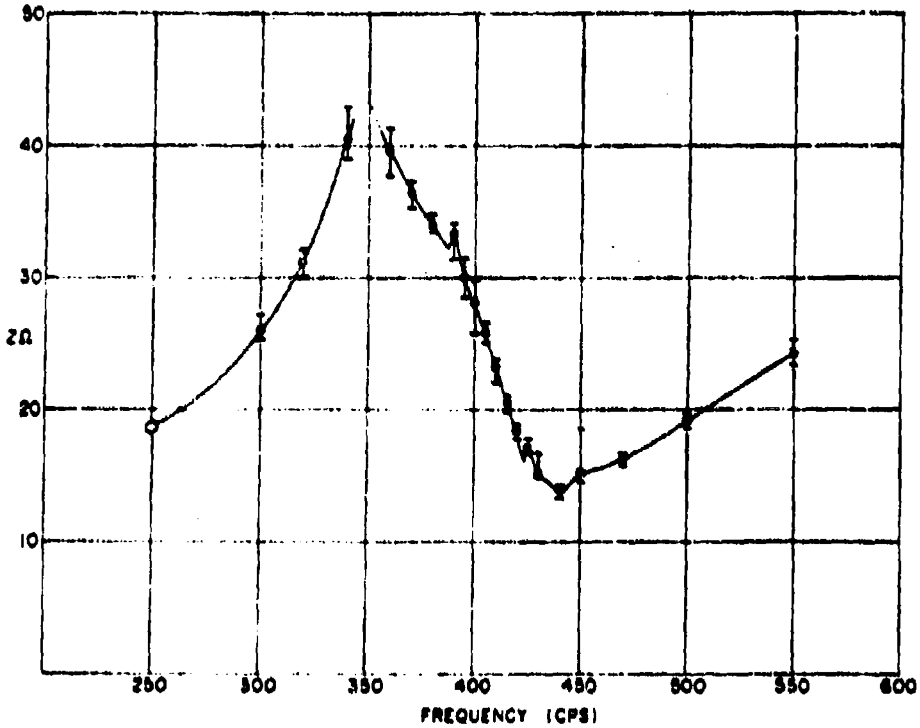

Fig. 5 - Averaged value of total transducer impedance

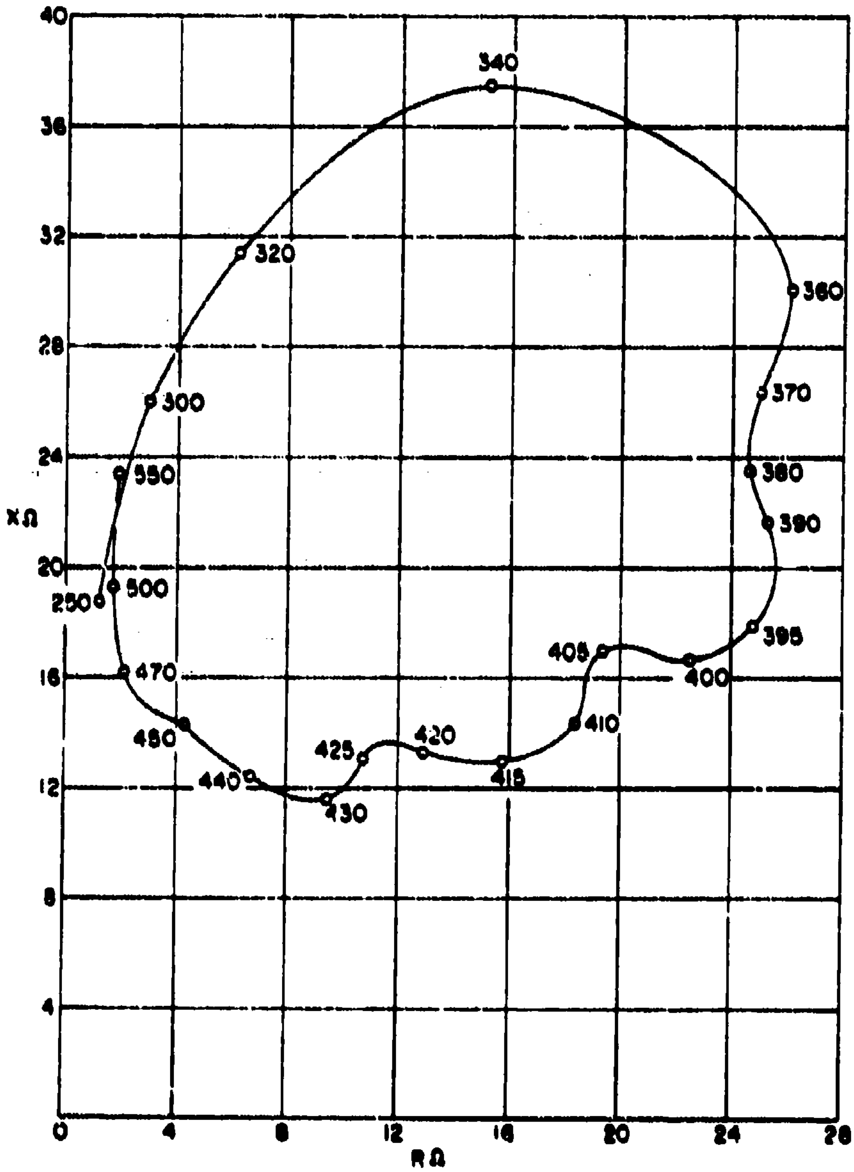

Fig. 6 - Vector impedance locus

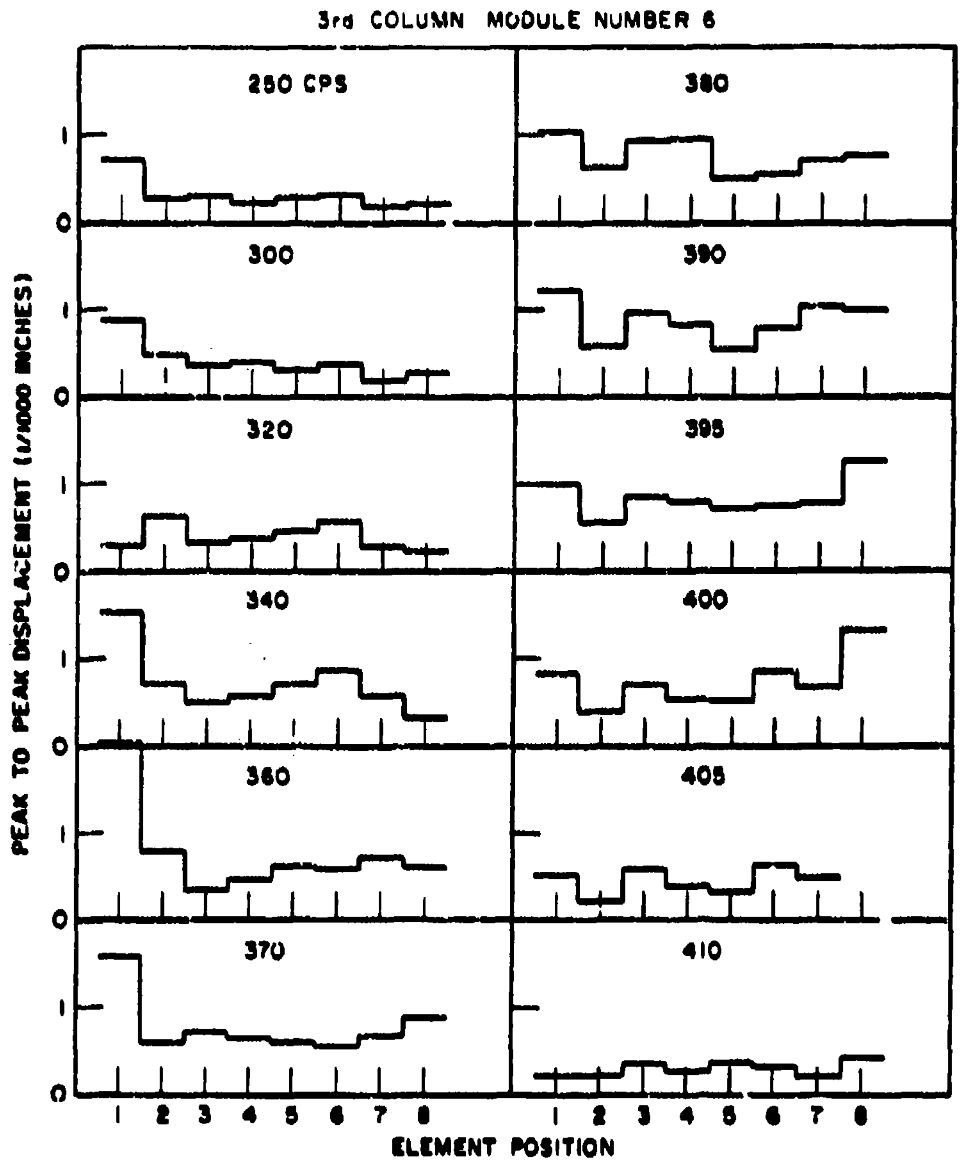

Fig. 7a - Amplitude of transducer element displacement

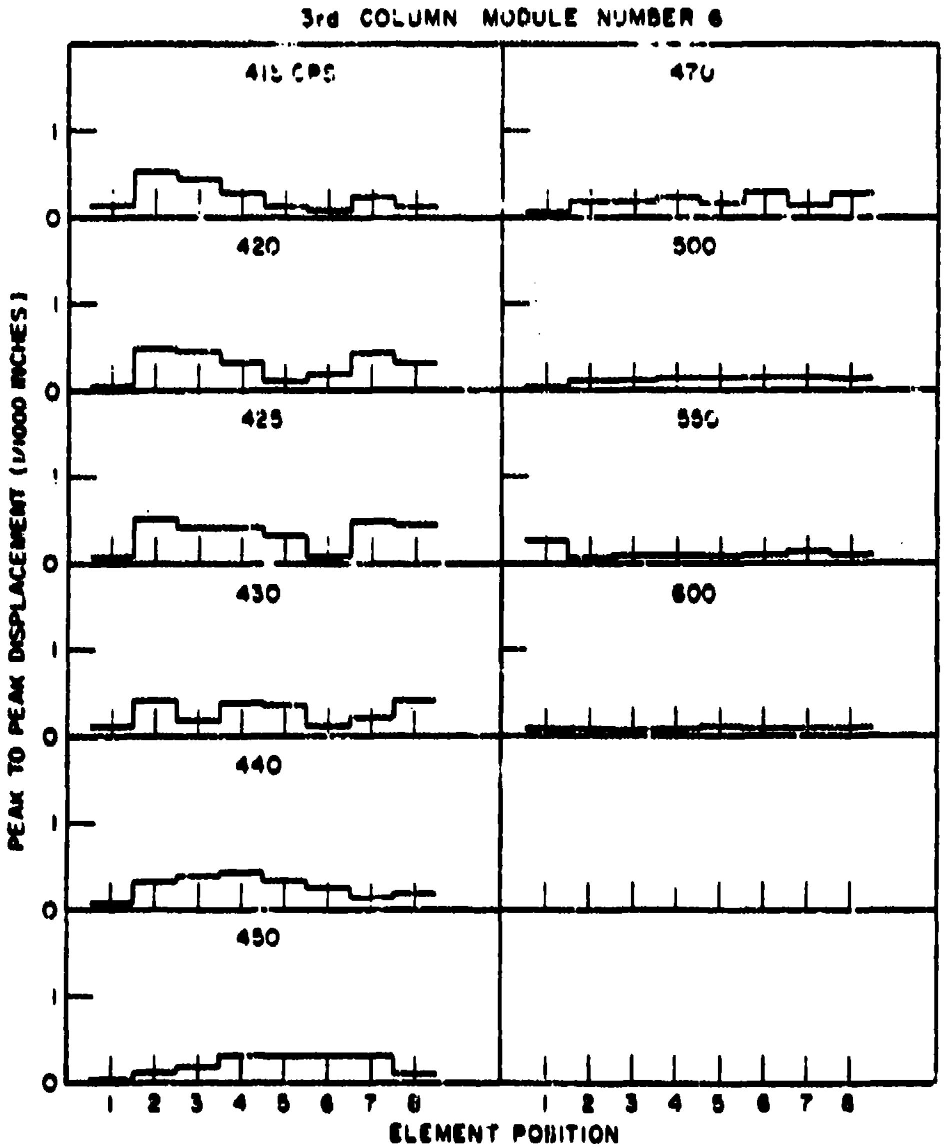

Fig. 7b - Amplitude of transducer element displacement

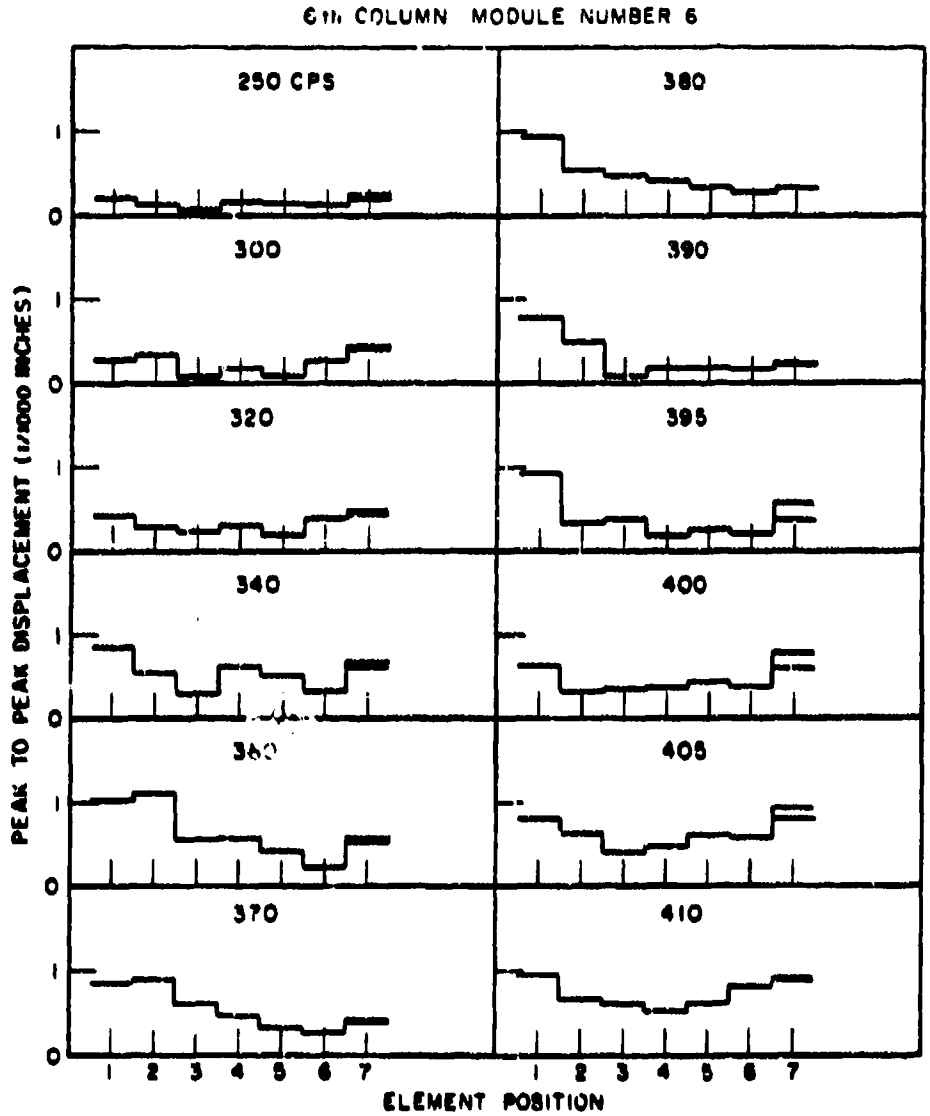

Fig. 8a - Amplitude of transducer element displacement

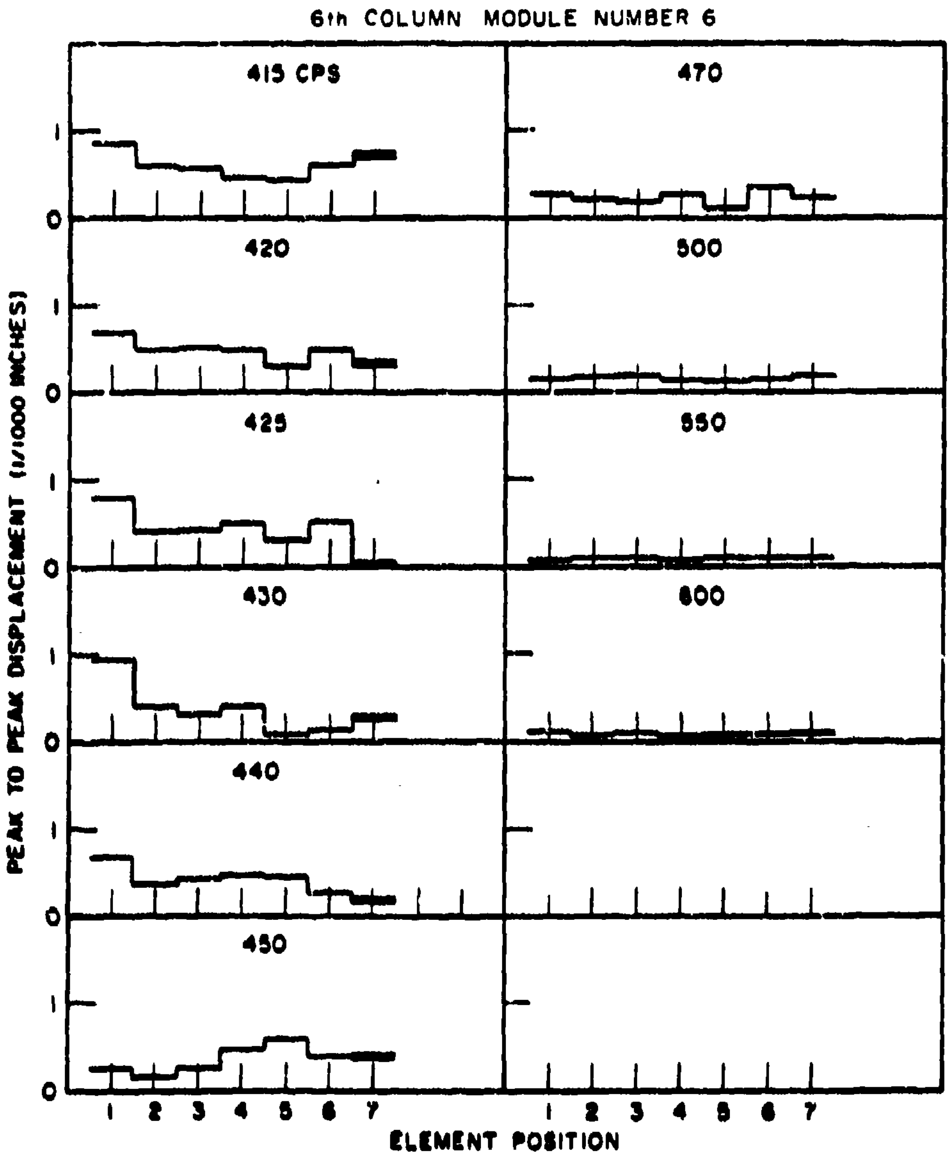

Fig. 8b - Amplitude of transducer element displacement

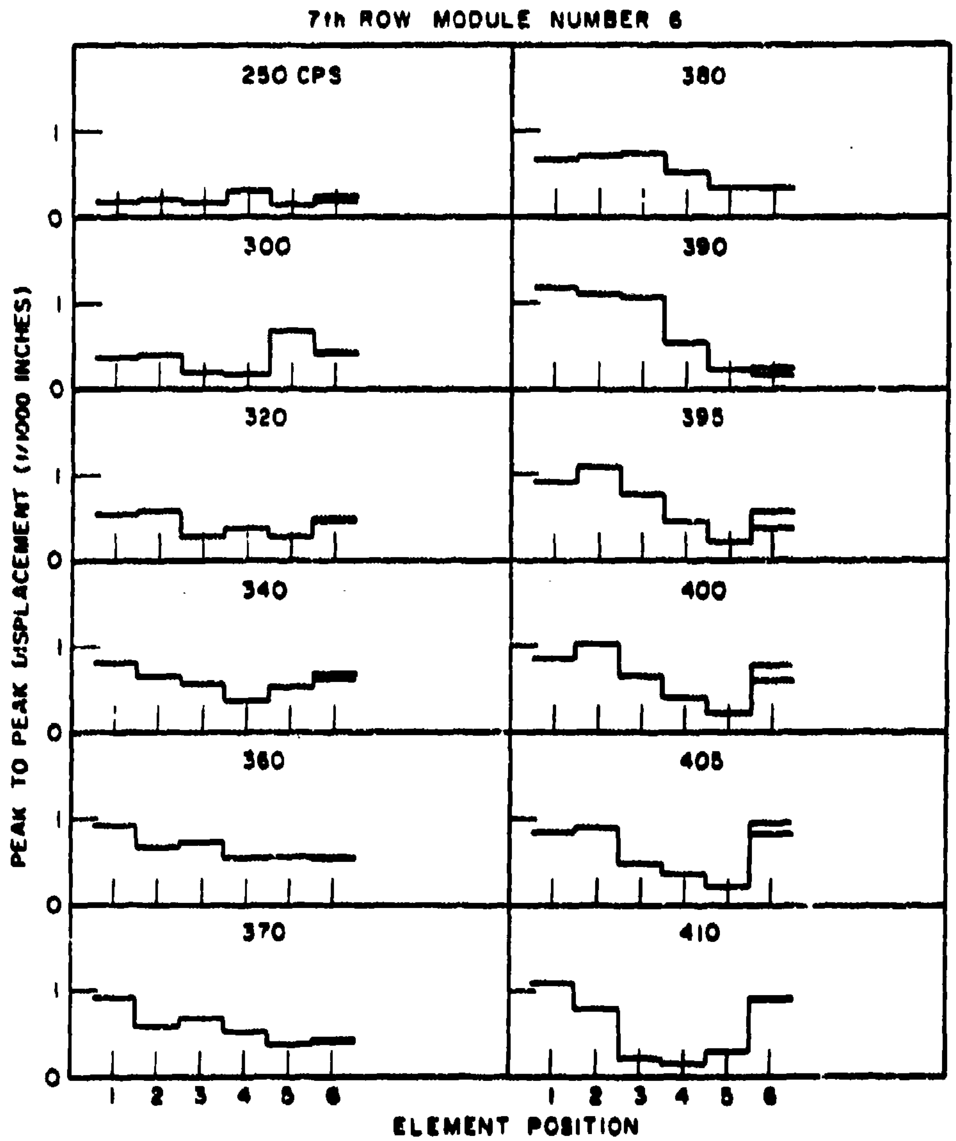

Fig. 9a - Amplitude of transducer element displacement

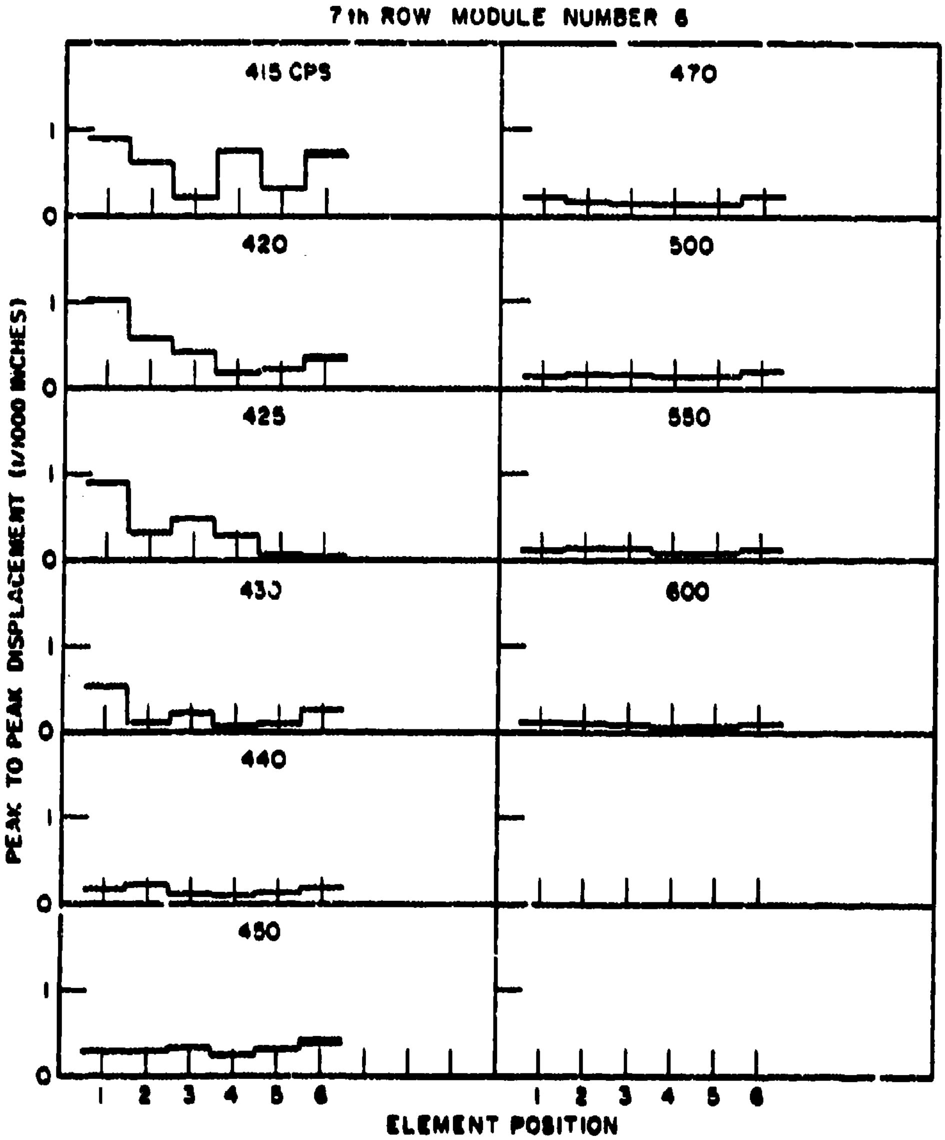

Fig. 9b - Amplitude of transducer element displacement

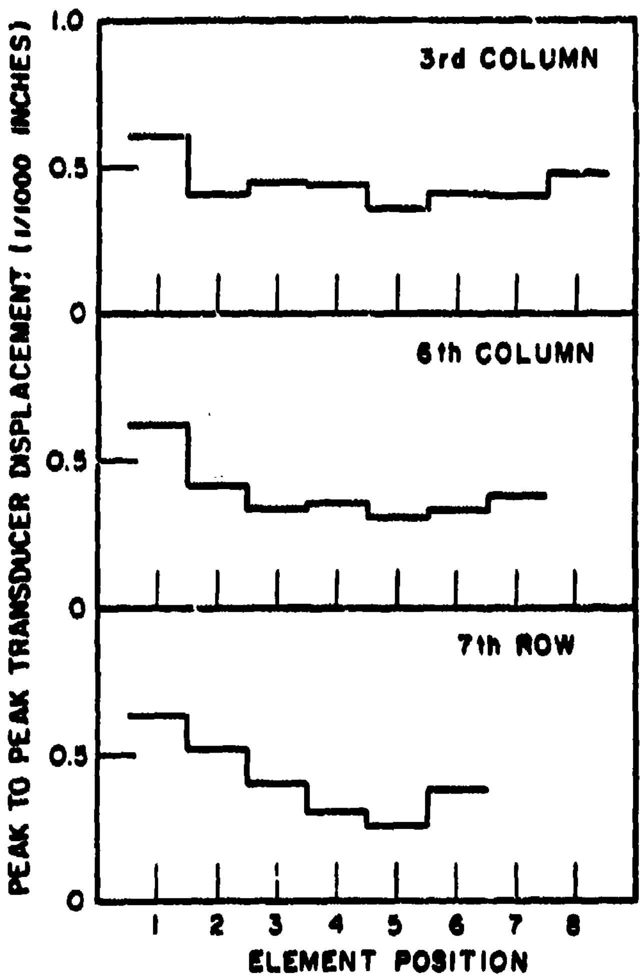

Fig. 10 - Displacement characteristics averaged over frequency band

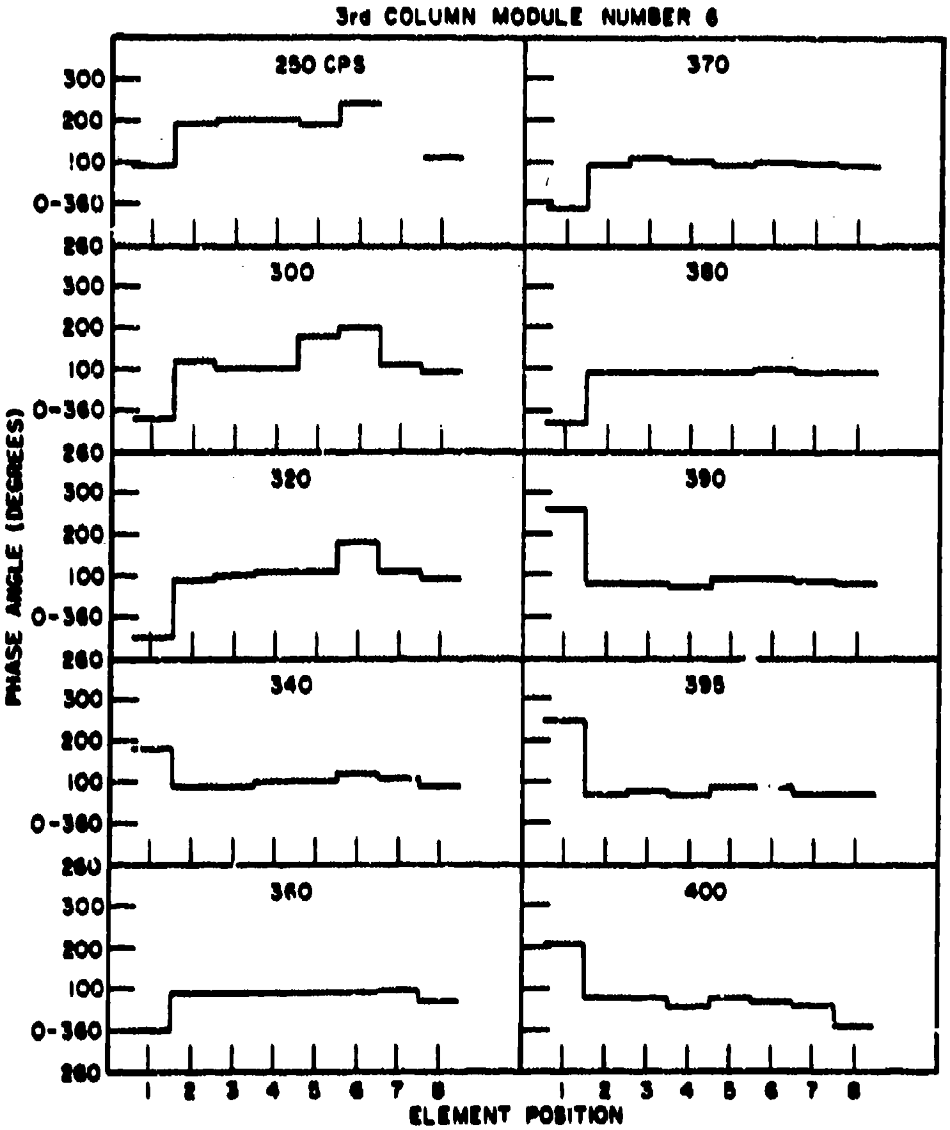

Fig. 11a - Phase characteristics

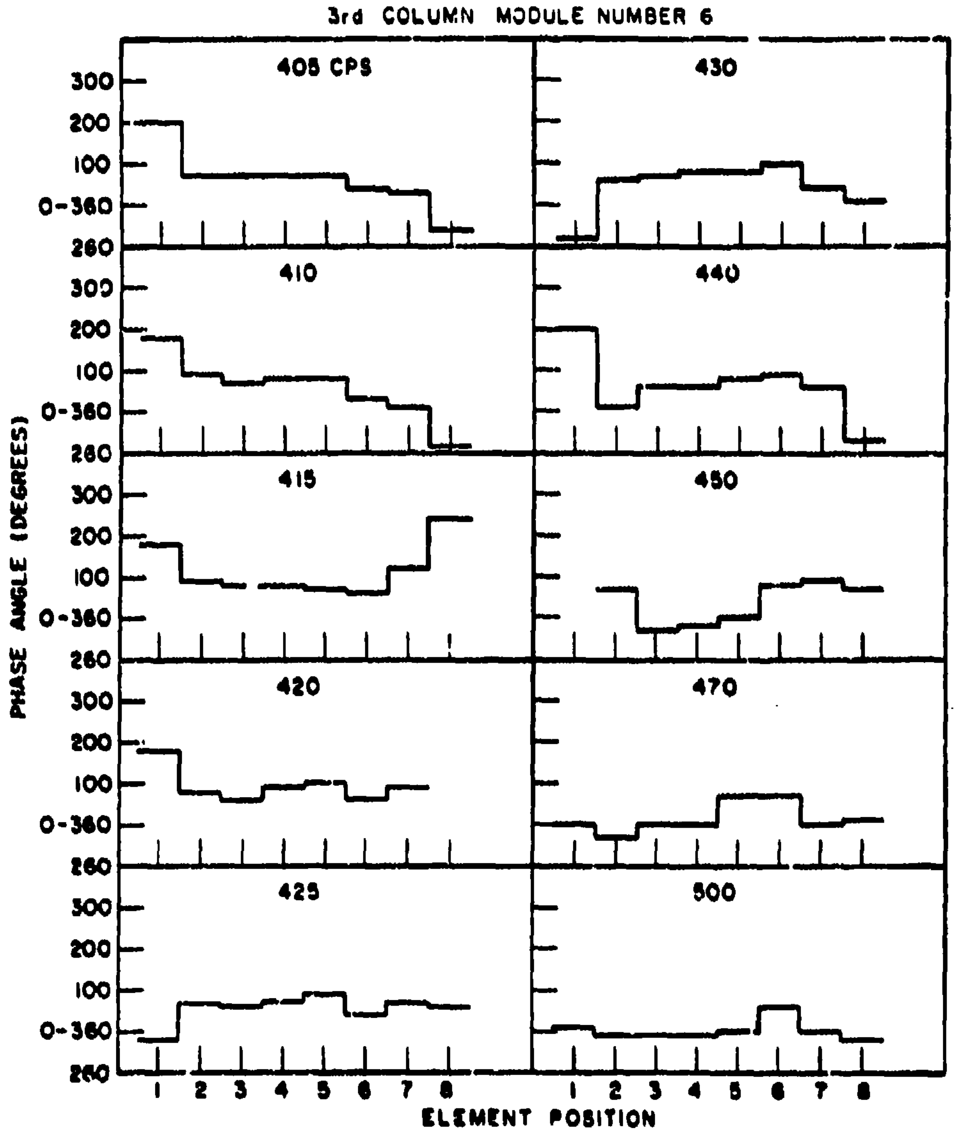

Fig. 11b - Phase characteristics

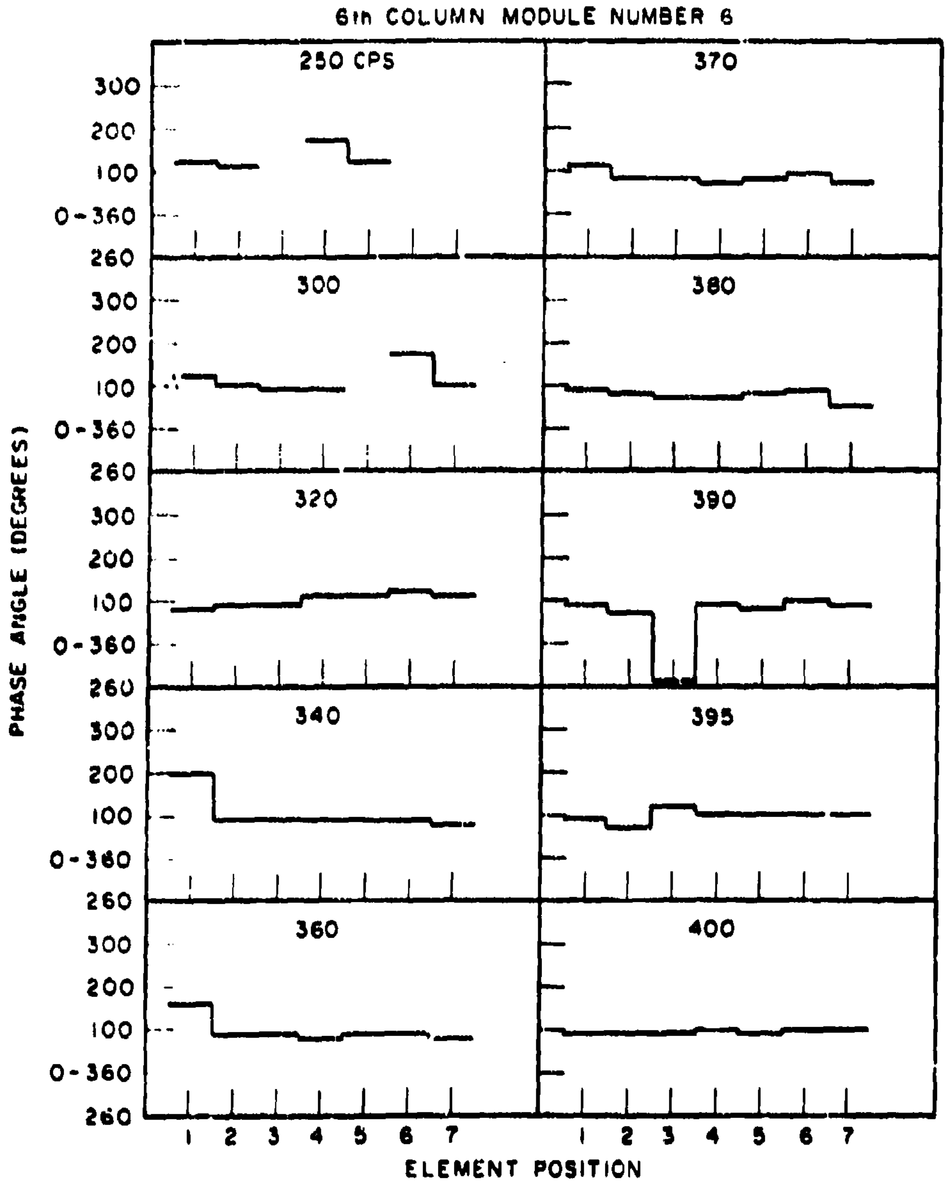

Fig. 12a - Phase characteristics

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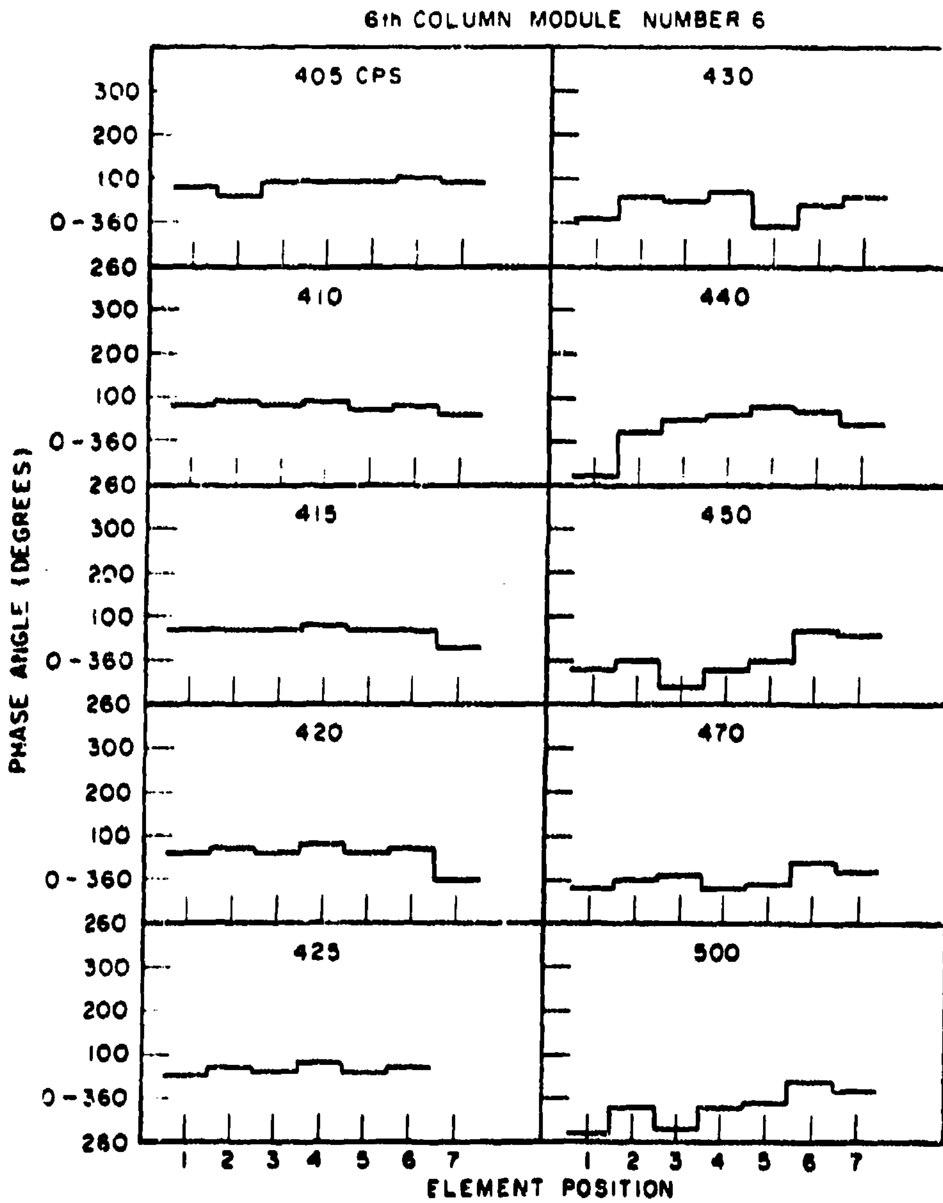

Fig. 12b - Phase characteristics

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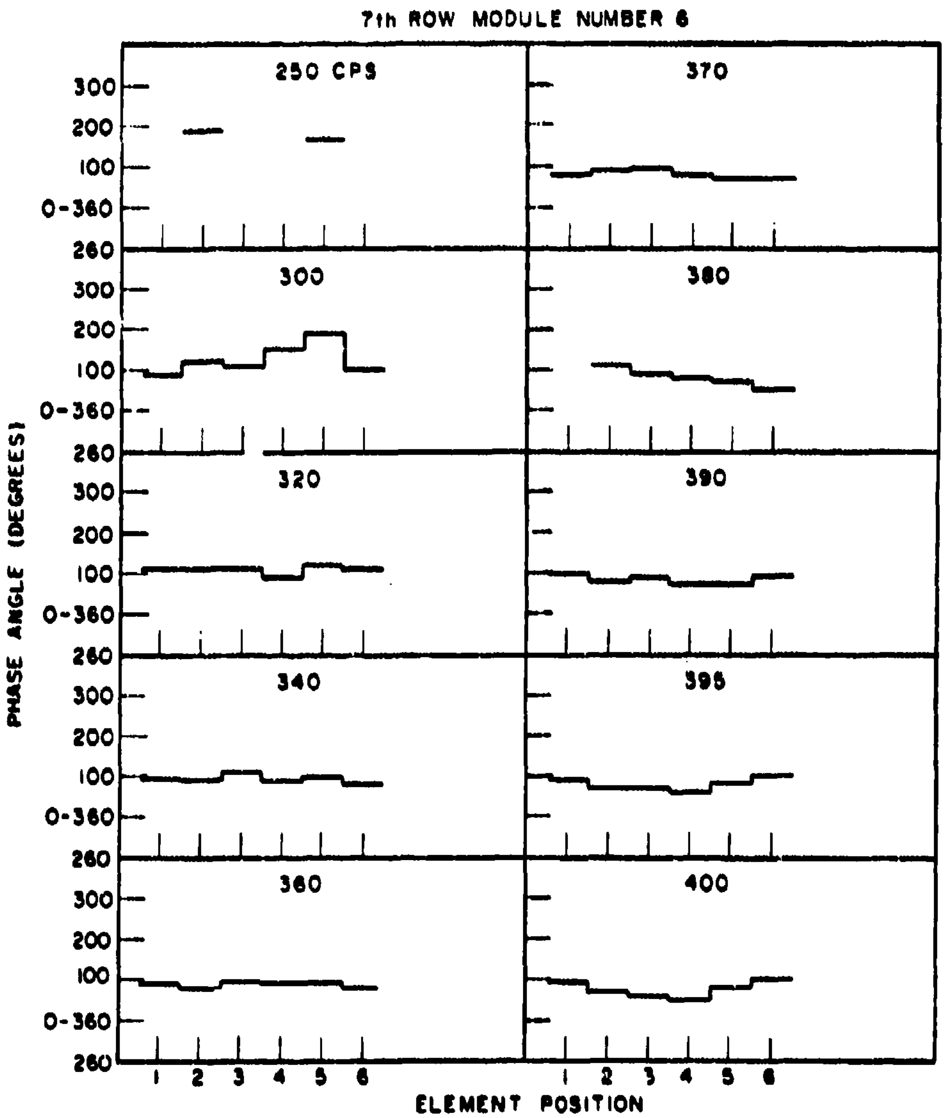

Fig. 13a - Phase characteristics

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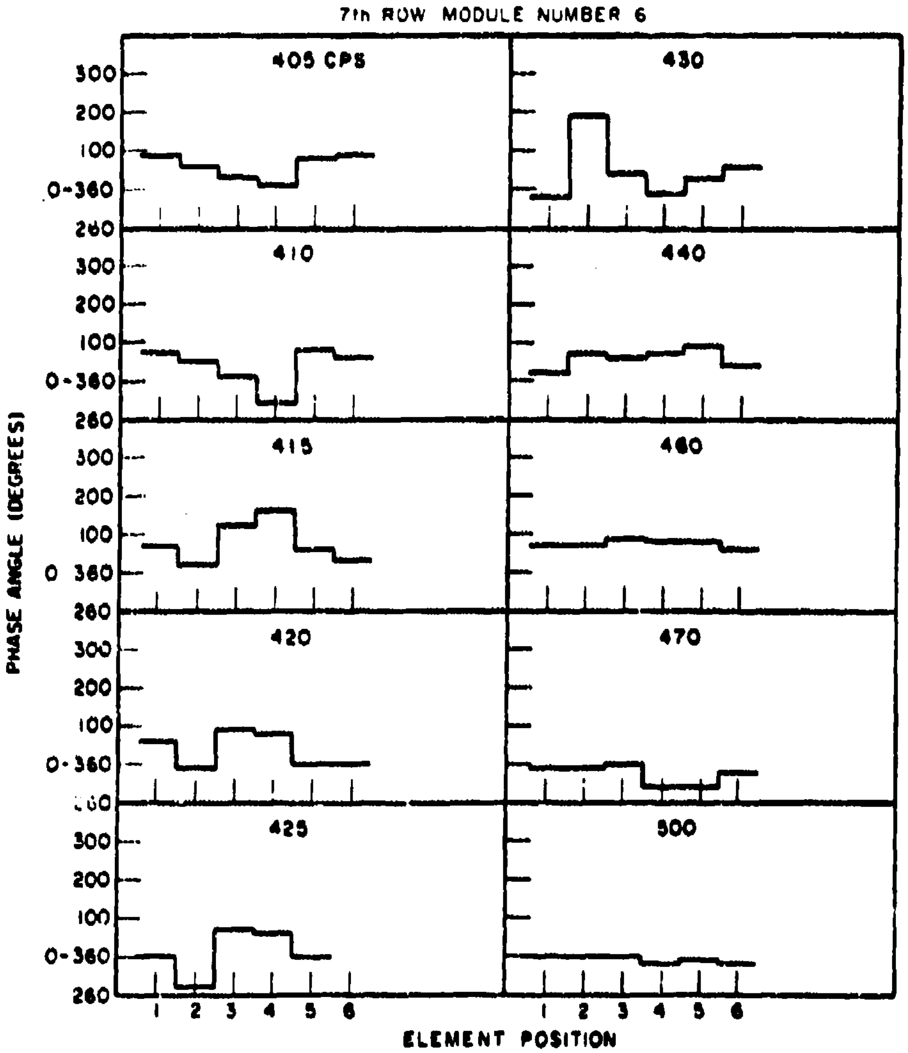

Fig. 13h - Phase characteristics

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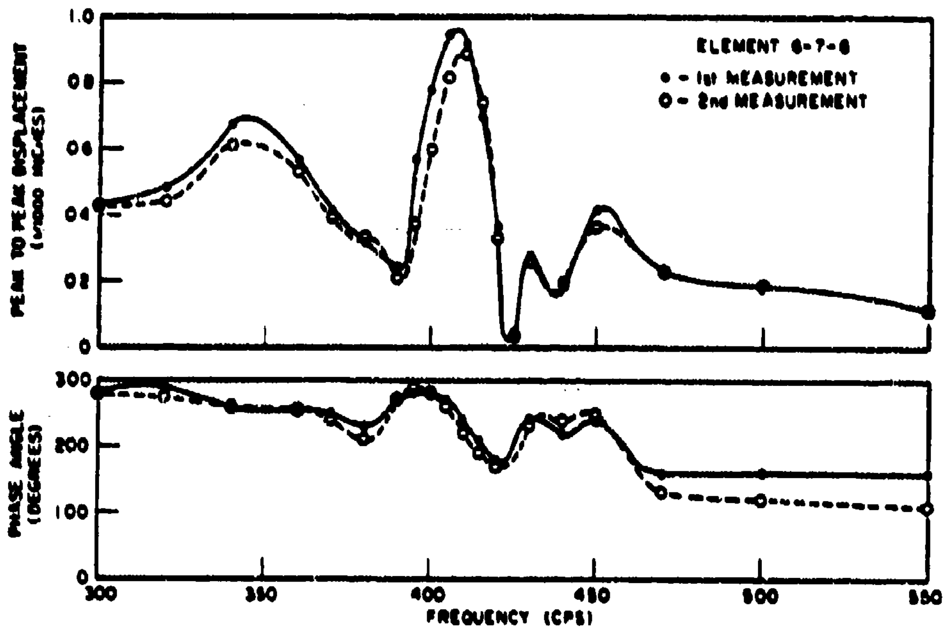

Fig. 14 - Repeatability of phase and displacement measurements

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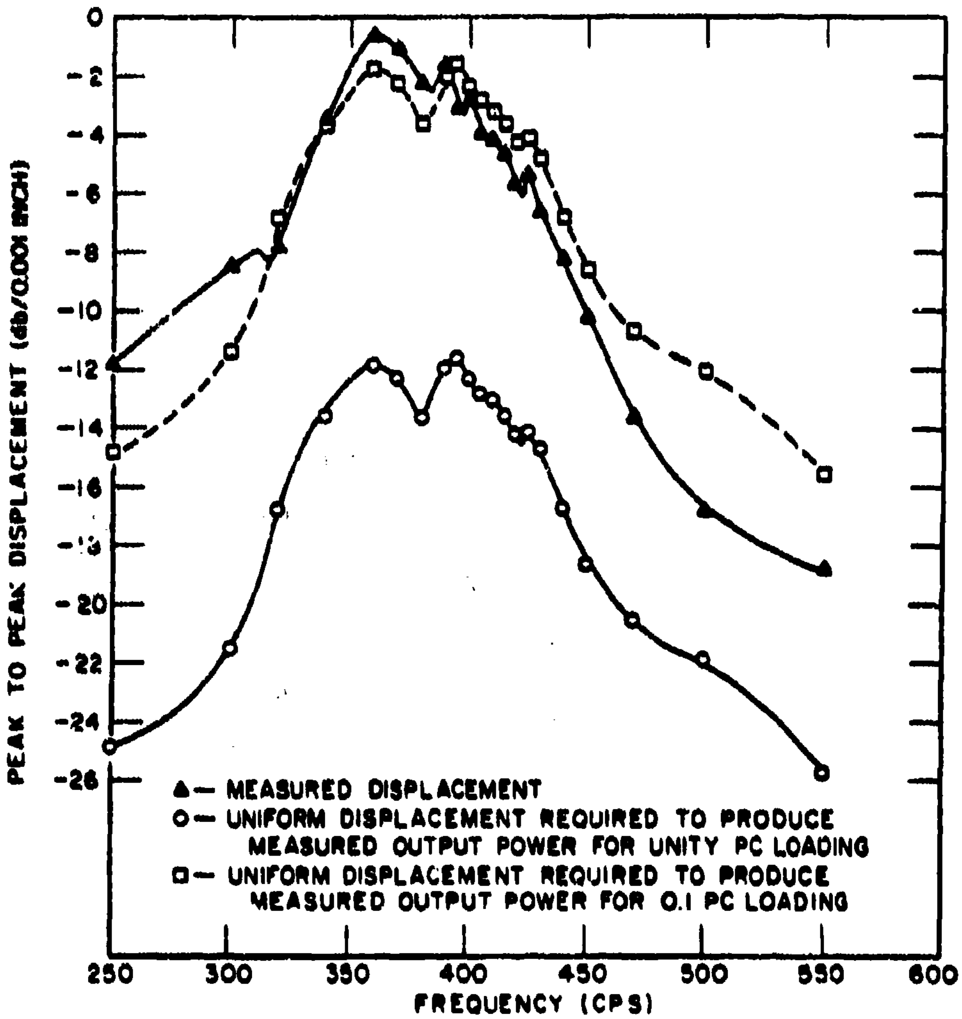

Fig. 15 - Transducer loading characteristics

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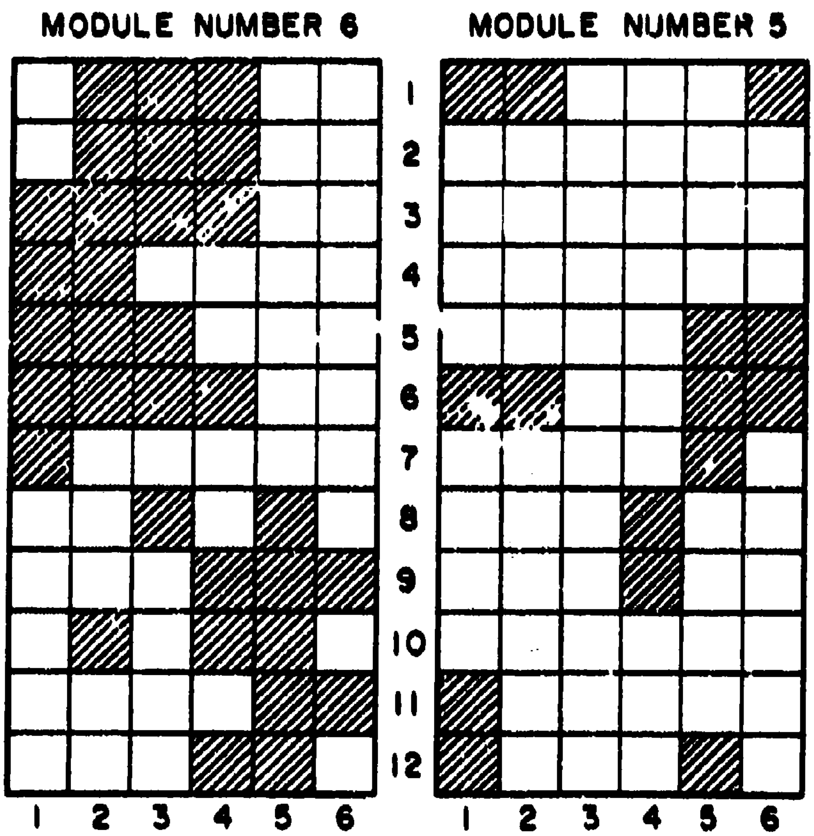

Fig. 16 - Pattern of transducer elements exhibiting probable damage

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UNITED STATES GOVERNMENT

Memorandum

7100-016

DATE: 22 January 2004

REPLY TO ATTN OF: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF (A) FOR DECLASSIFICATION

TO: Code 1221.1

REF: (a) "Project ARTEMIS High Power Acoustic Source", A.T. McClinton, R.H. Ferris, W.A. Herrington, Sound Div., NRL Memo Report 1205, 3 Aug 1961 (U)
(b) "Project ARTEMIS High Power Acoustic Source Second Interim Report on Acoustic Performance", A.T. McClinton and R.H. Ferris, Sound Division, NRL Memo Report 1214, 19 September 1961 (U)
(c) "Project ARTEMIS High Power Acoustic Source Third Interim Report on Acoustic Performance", A.T. McClinton, R.H. Ferris, Sound Division, NRL Memo Report 1273, 23 April 1962 (U)
(d) "Project ARETMIS High Power Acoustic Source Effect of Transducer Element Electrical Connection on Interaction in a Consolidated Array", A.T. McClinton, Sound Division, NRL Memo Report 1323, 4 June 1962 (U)
(e) "Test of Project ARTEMIS Source", R.H. Ferris, Sound Division, NRL Memo Report 1648, 15 September 1965 (U)
(f) "Power Limitations and Fidelity of Acoustic Sources", R.H. Ferris and F.L. Hunsicker, Sound Division, NRL Memo Report 1730, November 1966 (U)
(g) "Project ARTEMIS Acoustic Source Acoustic Test Procedure", R.H. Ferris and C.R. Rollins, Sound Division, NRL Memo Report 1769, 5 June 1967 (U)
(h) "Calibration of the ARTEIS Source and Receiving Array on the Mission Capistrano", M. Flato, Acoustics Div., NRL Memo Report 2712, Dec 1973 (U)
(i) "Theoretical Interaction Computations for Transducer Arrays, Including the Effects of Several Different Types of Electrical Terminal Connections", R.V. Baier, Sound Division, NRL Report 6314, 7 October 1965 (U)
(j) "Project ARTEMIS Acoustic Source Summary Report", NRL Report 6535, September 1967 (U)

1. References (a) thru (j) are a series of reports on Project ARTEMIS Reports by the Sound Division that have previously been declassified.

2. The technology and equipment of reference (a) have long been superseded. The current value of these papers is historical

3. Based on the above, it is recommended that reference (a) be available with no restrictions.

Burton G. Hurdle

BURTON G. HURDLE
NRL Code 7103

CONCUR:

Edward R. Franchi 1/23/2004

E.R. Franchi Date
Superintendent, Acoustics Division

CONCUR:

Tina Smallwood 1/28/04

Tina Smallwood Date
NRL Code 1221.1